CLAIMS

[c01] A robotic pen comprising:

a machine including a stage for mounting a workpiece for rotation and orthogonal translation, and an elevator for translation from said stage;

a pen tip rotatably mounted to said elevator;

a dispenser joined in flow communication with said pen tip for ejecting a stream of material atop said workpiece; and

a digital controller configured for coordinating relative movement of said pen tip and said stage, and dispensing of said stream from said pen tip.

[c02] A robotic pen according to claim 1 wherein said dispenser comprises:

a syringe for storing said material, and joined in flow communication with said pen tip; and

means for pumping said syringe to dispense material through said pen tip.

[c03] A robotic pen according to claim 2 wherein said controller is configured with a three-dimensional geometry of said workpiece and a predetermined path for said pen tip thereacross.

[c04] A robotic pen according to claim 3 wherein:

said stage includes a first table for translating said workpiece in a first linear axis, a second table for translating said workpiece in a second linear axis orthogonal to said first linear axis, and a spindle for rotating said workpiece in a first rotary axis; and

said pen tip is mounted to said elevator for translation in a third linear axis orthogonal to said first and second linear axes, and for rotation in a second rotary axis coordinated with said first rotary axis for orienting said pen tip obliquely with said workpiece.

[c05] A robotic pen according to claim 4 further comprising:

a vertical tube fixedly mounted thereto, and disposed in flow communication with said dispenser;

a tubular shaft fixedly mounted to said tube in flow communication therewith;

a manifold disk rotatably mounted around said shaft in flow communication therewith, and having said pen tip extending radially outwardly therefrom; and

means for rotating said disk on said shaft in said second rotary axis for positioning said pen tip relative to said spindle.

[c06] A robotic pen according to claim 5 wherein said disk rotating means comprise:

a first cog wheel joined to said disk, and rotatably mounted to said shaft;

a motor fixedly mounted to said elevator and including a second cog wheel mounted to an output shaft thereof; and

a cog belt joining together said first and second cog wheels.

[c07] A method of using said robotic pen according to claim 4 comprising:

mounting said workpiece in said stage;

coordinating relative movement between said pen tip and said workpiece to position said tip closely adjacent to and obliquely with a portion of said workpiece;

ejecting said stream from said tip atop said workpiece; and

moving said workpiece relative to said tip to write a line of said material atop said workpiece.

[c08] A method according to claim 7 further comprising maintaining a substantially constant gap between said pen tip and said workpiece during relative rotary movement therebetween.

[c09] A method of making said robotic pen according to claim 4 comprising:

removing a milling tool spindle from an elevator in a pre-existing computer numerically controlled milling machine; and

replacing said spindle with said pen tip rotatably mounted to said elevator.

[c10] A method according to claim 9 further comprising joining a personal computer to said dispenser and controller for coordinating dispensing of said stream with relative movement of said pen tip and said workpiece.

[c11] A robotic pen comprising:

a computer numerically controlled machine including a stage for mounting a workpiece for rotation and orthogonal translation, and an elevator for translation from said stage;

a pen tip rotatably mounted to said elevator; and

a dispenser joined in flow communication with said pen tip for ejecting a stream of material atop said workpiece.

[c12] A robotic pen according to claim 11 wherein:

said stage includes a first table for translating said workpiece in a first linear axis, a second table for translating said workpiece in a second linear axis orthogonal to said first linear axis, and a spindle for rotating said workpiece in a first rotary axis; and

said pen tip is mounted to said elevator for translation in a third linear axis orthogonal to said first and second linear axes, and for rotation in a second rotary axis coordinated with said first rotary axis for orienting said pen tip obliquely with said workpiece.

[c13] A method of using said robotic pen according to claim 11 comprising:

mounting said workpiece in said stage;

coordinating relative movement between said pen tip and said workpiece to position said tip closely adjacent to and obliquely with a portion of said workpiece;

ejecting said stream from said tip atop said workpiece; and

moving said workpiece relative to said tip to write a line of said material atop said workpiece.

[c14] A method according to claim 13 further comprising maintaining a substantially constant gap between said pen tip and said workpiece during relative rotary movement therebetween.

[c15] A method according to claim 14 further comprising maintaining said gap using open loop control based on three dimensional geometry of said workpiece.

[c16] A method according to claim 14 further comprising maintaining said gap using closed loop feedback control thereof.

[c17] A robotic pen according to claim 12 wherein said elevator includes:

a vertical tube fixedly mounted thereto, and disposed in flow communication with said dispenser;

a tubular shaft fixedly mounted to said tube in flow communication therewith;

a manifold disk rotatably mounted around said shaft in flow communication therewith, and having said pen tip extending radially outwardly therefrom; and

means for rotating said disk on said shaft in said second rotary axis for positioning said pen tip relative to said spindle.

[c18] A robotic pen according to claim 17 wherein said disk rotating means comprise:

a first cog wheel joined to said disk, and rotatably mounted to said shaft;

a motor fixedly mounted to said elevator and including a second cog wheel mounted to an output shaft thereof; and

a cog belt joining together said first and second cog wheels.

[c19] A robotic pen according to claim 12 further comprising a digital controller configured for coordinating relative movement of said pen tip and said spindle in said first, second, and third linear axes and said first and second rotary axes.

[c20] A robotic pen according to claim 19 wherein said five-axis controller is integral with said machine, and said machine is a pre-existing milling machine modified by removing from said elevator the milling spindle thereof and replaced by said pen tip rotatably mounted thereto.

[c21] A robotic pen according to claim 19 wherein said controller is configured with a three-dimensional geometry of said workpiece and a predetermined path for said pen tip thereacross.

[c22] A robotic pen according to claim 12 wherein said dispenser comprises:

a syringe for storing said material, and joined in flow communication with said pen tip; and

means for pumping said syringe to dispense material through said pen tip.

[c23] A robotic pen according to claim 22 further comprising means for coordinating dispensing of said material from said dispenser with relative movement between said pen tip and workpiece to control flowrate of said stream from said pen tip.